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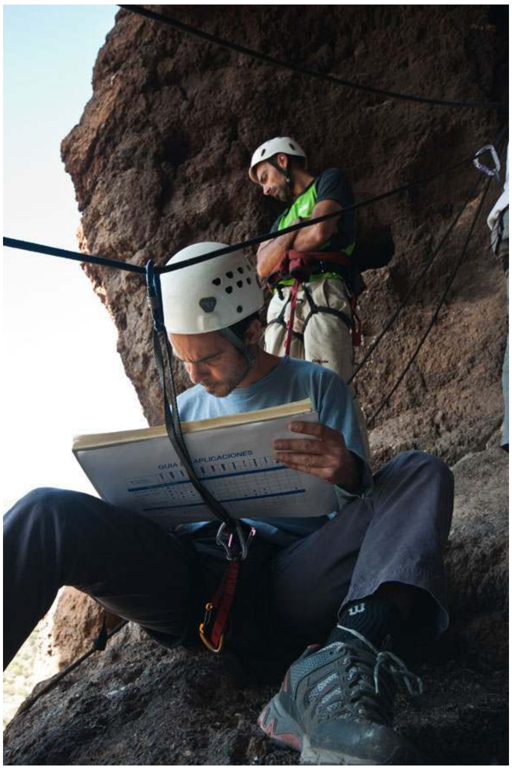
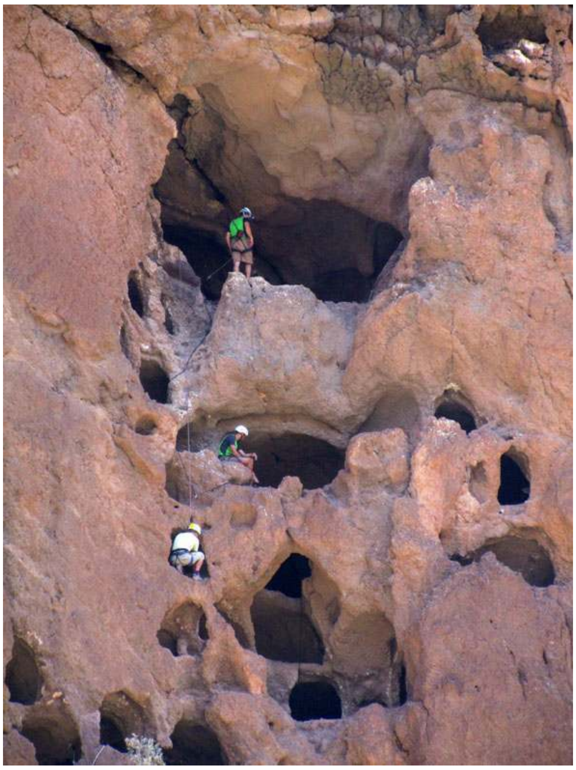
Illustrated prologue

Most Pre-Hispanic granaries in Gran Canaria are found along inaccessible cliffs requiring specialised climbing equipment and good physical condition to safely reach them. Archaeologists carrying out surveys and silo sampling must wear helmets and be secured by ropes and harnesses while a professional team of climbers supervise security procedures.



Archaeologists recording data at the cliff granary of Temisas, Risco Pintado
photograph by E. Martín-Rodríguez

Archaeologists and climbing specialists during their ascent to the granary of El Álamo-Acusa
photograph by J. Morales



Archaeologists and climbing specialists during their ascent to the granary of Cuevas Muchas, Guayadeque

photograph by V. Barroso

Introduction

The long-term storage of food is a key strategy to cope with seasonal and annual shortages, allowing populations access to food for a longer period after harvesting and minimising the risks of famines provoked by unpredictable environmental fluctuations (Halstead & O'Shea 1989; Kuijt 2009; Winterhalder & Goland 1997; Wintherhalder *et al.* 2015). In order to preserve the food, people have developed different techniques such as controlling the temperature, humidity, and amount of oxygen in food containers, as well as protecting food from insects and other pests (Beckett 2011).

1 Insect pests are in fact one of the main problems for the long-term storage of food, especially for grains. It is estimated that before chemical insecticides were used systematically, insects damaged around 10-20 % of the stored grain, and in certain conditions they could destroy the whole harvest (Abdalla *et al.* 2001; Buckland 1991). This is the case of long-term storage because spoilage rates in grains increase exponentially from year to year (Abdalla *et al.* 2001; Buckland 1991). Nowadays, decay of food reserves is still a major concern that has led to considerable research on the amount of grain lost during this stage (Alonso-Amelot & Avila-Núñez 2011; Beckett 2011).

2 Historical documents record the use of organic and inorganic products to kill or dispel insects from stores. Yet there is little archaeological data about this important aspect in food storage (Panagiotakopulu *et al.* 1995). This is partially due to the lack of in situ finds of conserved ancient foods. Perishable material such as seeds, leaves, cordage, straw, skin, etc. are only preserved in exceptional conditions (Peña-Chocarro *et al.* 2015).

Consequently, knowledge of storage methods in the archaeological record is limited (Groenewoudt 2011; Kent 1999).

3 This paper aims to provide new data on the methods and techniques employed in the past for the long-term storage of food plants by presenting the preliminary results of an analysis carried out in the framework of a multidisciplinary project of a group of granaries on the Island of Gran Canaria (Canary Islands, Spain) from the Pre-Hispanic period (*ca.* 500-1500 AD). The indigenous populations of Gran Canaria were farmers that procured most of their food from cultivated plants and they built many granaries for their storage (Arnay-de-la-Rosa *et al.* 2010; Delgado-Darias *et al.* 2005; González-Reimers & Arnay-de-la-Rosa 1992; Velasco-Vázquez *et al.* 1999). Granaries with their respective silos offer excellent conditions for preservation of organic materials and in certain cases still contain archaeological remains of crops as well as other plants in the form of leaves, cordage, etc., or insects and animal bones. They also preserve an assortment of Canarian material culture such as lithic tools, pottery, and terracotta figurines. This study focuses on six granaries and their contents following the methods of archaeobotanical and archaeoentomological research, as well as those of morpho-technical/functional stone tool and spatial analyses. Ethnographic studies on storage techniques by traditional populations of North Africa and the Canaries also provide models serving to interpret the archaeological record. Furthermore, this paper presents and discusses the significance of this still preliminary data.

Materials & Methods

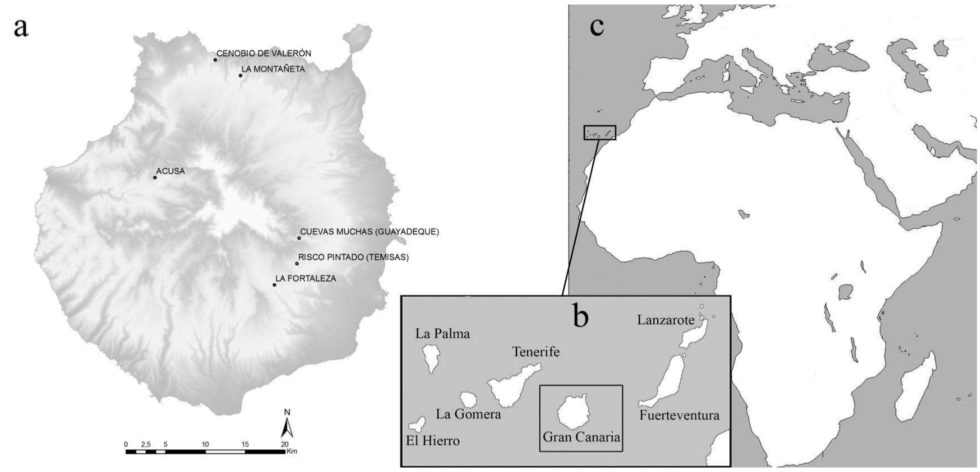
The sites

According to archaeological and genetic data, the different Canary Islands were first populated between the 2nd century BC and the 2nd century AD by Berber populations from north-western Africa. Yet the question of exact chronology and geographical origin of the first human colonisation of the archipelago remains open (Maca-Meyer *et al.* 2004). Those firsts colonists introduced domestic animals and crops that became their staple food (Hagenblad *et al.* 2017; Olalde *et al.* 2015). In the case of Gran Canaria, palaeodiet information from archaeological human remains (Delgado-Darias *et al.* 2005; Velasco *et al.* 1999) and textual evidence from the first Europeans arriving in the archipelago in the 14-15th centuries AD (Abreu-Galindo 1977 [1602]; Morales-Padrón 1993 [1500/1525]) indicate that agriculture was the main provider of food. Although agriculture was practiced in the other islands, it played a secondary role in the diet in comparison to foods of animal origin. Moreover, the other islands offer no archaeological evidence of granaries.

4 Although storage facilities in Gran Canaria are very common, they have not been the object of systematic analysis prior to this project. In spite of the different types of containers used to store food, this study focuses exclusively on communal granaries or fortified granaries. In general terms, communal granaries comprise a group of silos carved into the rock and located at inaccessible places such as cliffs. It is noteworthy that the communal granaries of Gran Canaria resemble the *igoudar* or *magasins de falaise* of the Berber populations in Morocco and other parts of the Maghreb (Onrubia-Pintado 1995; Ramou & Asmhri 2013). The current study therefore presents preliminary data gleaned from analyses carried out in six Canarian granaries: Cenobio de Valerón, La Montañeta, El

Álamo-Acusa, Cuevas Muchas-Guayadeque, Risco-Pintado-Temisas and La Fortaleza (fig. 1).

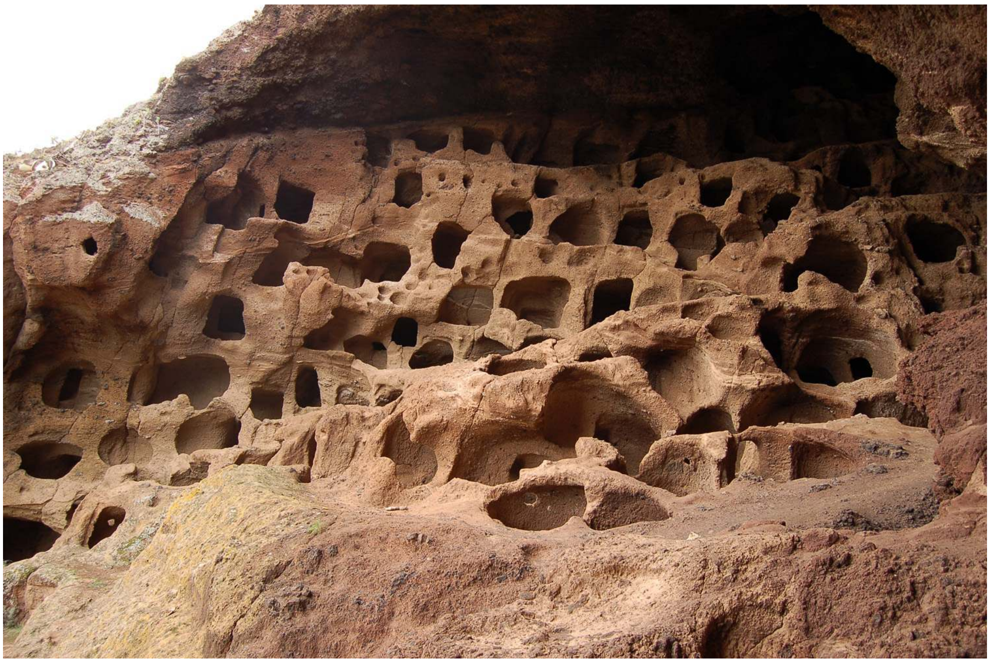
Figure 1.



Map of the studied area: a) location of sites mentioned in the text; b) geography of the Canary Islands; c) location of the Canary Islands.

5 The granary of Cenobio de Valerón is located on a cliff in the north of Gran Canaria at 263 m asl. Its approximately 300 silos, the largest group on the island, are carved inside a large natural cave measuring 27 x 20 m (fig. 2). Due to the monumentality of the site, the silos were repeatedly plundered and therefore contain less remains than the other granaries. Five radiocarbon dates carried out on plant remains recovered in the silos indicate that the site saw use from 1040 to 1440 cal AD (Naranjo-Mayor & Rodríguez-Rodríguez, 2015).

Figure 2.



General view of the granary of Cenobio de Valerón

photograph by J. Morales

6 La Montañeta is a large site comprising both natural and man-made caves with several chambers serving as granaries (Velasco-Vázquez *et al.* 2001). The site is located in the north of Gran Canaria, at 390 m asl, and less than 4 km from the granary of Cenobio de Valerón (fig. 1). Three radiocarbon analyses of charred plants and animal bones recovered in the silos indicate that the site spanned 690 to 1320 cal AD (fig. 3).

Figure 3.

Context (silo)	sample identification	common name	^{14}C (BP)	Cal AD (95.4%)	reference
Zone 10, Silo 15	*Hordeum vulgare*	barley	520 ± 30 (Beta-384697)	1330 - 1440	Naranjo-Mayor & Rodríguez-Rodríguez, 2015
Zone 8, Silo 38	*Hordeum vulgare*	barley	600 ± 30 (Beta-390473)	1295 - 1410	Naranjo-Mayor & Rodríguez-Rodríguez, 2015
Zone 10, Silo 11	*Hordeum vulgare*	barley	670 ± 30 (Beta-384696)	1275 - 1390	Naranjo-Mayor & Rodríguez-Rodríguez, 2015
Zone 8, Silo 10	*Hordeum vulgare*	barley	780 ± 30 (Beta-390474)	1215 - 1280	Naranjo-Mayor & Rodríguez-Rodríguez, 2015
Zone 15, Silo 1	*Ficus carica*	fig	890 ± 30 (Beta-384698)	1040 - 1220	Naranjo-Mayor & Rodríguez-Rodríguez, 2015
n/d	unidentified wood charcoal	charcoal	770 ± 30 (Beta-298968)	1220 - 1280	Unpublished
Level 4, Silo 2F	bone	bone	660 ± 30 (Beta-298967)	1280 - 1320	Unpublished
Level 3, Silo 15	*Hordeum vulgare*	barley	1220 ± 30 (Beta-298966)	690 - 890	Unpublished
Level 2, Silo 8	*Laurus novocanariensis*	Canarian bay leaf	980 ± 30 (Beta-317653)	1020 - 1150	Morales *et al*. 2014
Level 2, Silo 3	*Triticum durum*	hard wheat	600 ± 30 (Beta-317650)	1290 - 1410	Morales *et al*. 2014
Level 2, Silo 4	*Hordeum vulgare*	barley	540 ± 30 (Beta-317651)	1320 - 1430	Morales *et al*. 2014
Level 2, Silo 12	*Sitophilus granarius*	granary weevil	980 ± 30 (Beta 317653)	1020 - 1150	Morales *et al*. 2014
Level 3, Silo 3	*Laurus novocanariensis*	Canarian bay leaf	610 ± 30 (Beta-362107)	1290 - 1410	Unpublished
Level 3, Silo 5	*Hordeum vulgare*	barley	560 ± 30 (Beta-362104)	1310 - 1430	Hagenblad *et al*. 2017
Level 4, Silo 5	*Hordeum vulgare*	barley	710 ± 30 (Beta-362105)	1260 - 1380	Hagenblad *et al*. 2017
Level 3, Silo 9	*Hordeum vulgare*	barley	630 ± 30 (Beta-362106	1280 - 1400	Hagenblad *et al*. 2017
Level 2, Silo 1	*Hordeum vulgare*	barley	610 ± 30 (Beta-362110)	1290 - 1410	Hagenblad *et al*. 2017
Level 2, Silo 3	*Hordeum vulgare*	barley	860 ± 30 (Beta-362111)	1050 - 1250	Hagenblad *et al*. 2017
Level 1, Silo 8	*Hordeum vulgare*	barley	550 ± 30 (Beta-362112)	1320 - 1430	Hagenblad *et al*. 2017
Level 1, Silo 12	*Hordeum vulgare*	barley	520 ± 30 (Beta-362113)	1330 - 1440	Hagenblad *et al*. 2017
Level 1, Silo 1	*Laurus novocanariensis*	Canarian bay leaf	510 ± 30 (Beta-362109)	1400 - 1440	Unpublished
Silo 31	*Hordeum vulgare*	barley	790 ± 30 (Beta-347796)	1210 - 1280	Unpublished

Table listing the radiocarbon dates on archaeological remains from the granaries analysed.

7 El Álamo-Acusa is a granary linked to a large complex of caves (dwellings and burials) carved artificially in the cliff of the Acusa Plateau (Morales *et al.* 2014). The site is in the centre of the island at 945 m asl. It is organised in two levels: the lower served as a corral until recently, while the second, better preserved is more difficult to access (fig. 4). Some of the original content of its silos are still visible to the naked eye. The results presented

in this study come from 12 of upper level silos that have yielded radiocarbon dates between 1020 to 1430 cal AD (Morales *et al.* 2014).

Figure 4.

View of the access to the second level of the granary of El Álamo-Acusa
photograph by E. Martín-Rodríguez

8 The granary of Cuevas Muchas is located in eastern Gran Canaria in the Valley of Guayadeque at 700 m asl (Velasco-Vázquez *et al.* 2001). The site comprises *ca.* 50 silos arranged in four levels intercommunicated by channels carved into the volcanic rock. Three radiocarbon dates on silo plant remains indicate that the granary served between 1260 and 1430 cal AD (Hagenblad *et al.* 2017).

9 Temisas is a large complex of caves in the east of the island (695 m asl) carved artificially into the 'Risco Pintado' cliff that served as dwellings, burials and granaries (Velasco-Vázquez *et al.* 2001). The granary containing a total of about 35 silos is organised on two levels. Four radiocarbon dates of plant remains in the silos yield a range from 1050 to 1440 cal AD (Hagenblad *et al.* 2017).

10 The site of La Fortaleza comprises both natural and artificial caves at the peak (510 m asl) of a mountain (Schlueter-Caballero 2009) in the middle of the Caldera of Tirajana, a huge depression in the centre of the island. The site includes dwellings, burials, a ritual altar at the top of the peak, and granaries. A radiocarbon date obtained from plant remains in a silo indicates that the granary saw use at least between 1210 and 1280 cal AD (fig. 3).

Methods of analyses

In order to understand the activities carried out in the granaries, several analyses were carried out regarding both the sites and their archaeological remains. The following paragraphs present a short description of the analyses.

Spatial analysis

The pattern of geographical distribution of the granaries throughout the Island of Gran Canaria was analysed by means of the Geographical Information System (ArcGis 10.0). The maps consulted for the study are based in two main sources. Soil classification followed the lines advanced in the cartography of J. Diaz (1995). Soils were classified according to their potential for agriculture (types B and C) and for pastures (types D and E); high-quality soil type A is no present in Gran Canaria. The 1:5000 digital elevation model of Gran Canaria provided by GRAFCAN, in turn, served for the analyses of relief.

11 The different cartographical analyses resulted in a series of isochrone maps combining the granaries and their types of surrounding soils (see details in Moreno-Benítez & González-Quintero 2013-2014). The maps consist of lines made up of connecting points corresponding to equal 15-minute walks taking into considering the factors of distance and slope. Moreover, the maps took into consideration the surface (m^2) of the different types of soil in each isochrone. Viewsheds from the granaries were calculated using multiple points at 1.65 m of elevation from the surface. The results were analysed from the point of view of soil types and isochrones to attain evidence of the farm lands linked to the granaries.

Material culture (lithic industry)

Surveys of the granaries yielded several types of archaeological artefacts such as stone tools, carved wood or plant fibre implements. This paper offers a first approach to the lithic industry from the granary of Cenobio de Valerón. The assemblage of artefacts from this site consisted of grinding stones, knapped artefacts, and other types of ground stone tools systematically analysed from morpho-technical and functional perspectives (Adams 2002; Naranjo-Mayor & Rodríguez-Rodríguez, 2015; Naranjo-Mayor & Rodríguez-Rodríguez, 2016) so as to better understand their role in the activities carried out in the granaries.

Analysis of the macro-botanical remains

The analyses of sediment samples from the silos reveal the species of stored plants. A number of samples of the mortar covering the silos were also analysed for plant remains. The silos sampled in the study are currently uncovered but were almost certainly sealed at the moment of their use, as frames carved in the rock are still visible at their entrance and wood and stone gates have been recovered from past surveys on other granaries from Gran Canaria (Onrubia-Pintado 1995).

Figure 5.

Sites (granaries)		Cenobio de Valerón	La Montañeta	El Álamo-Acusa	Cuevas Muchas-Guayadeque	Temisas-Risco Pintado	La Fortaleza	
Cal AD radiocarbon dates		1040 to 1440	690 to 1320	1020 to 1430	1260 and 1430	1050 to 1440	1210 and 1280	**total**
Number of silos analyzed		14	5	12	47	34	2	114
volume of sediment in litres		53	n/d	14	47	34	2	150
Cultivated plants	**Common name**							
Hordeum vulgare L. subsp. *vulgare,* grain	barley	7	26	2	5	5	1	46
Hordeum vulgare L. subsp. *vulgare,* set of hulls	barley	-	-	950	368	335	33	1686
Hordeum vulgare L. subsp. *vulgare*, rachis	barley	26	9	5795	3871	935	69	10705
Triticum aestivum/durum, grain	wheat	-	1	2	2	9	4	18
Triticum durum Desf., rachis	wheat	1	-	403	512	71	12	999
Lens culinaris Medik., seed	lentil	-	1	61	3	65	-	130
Pisum sativum L., seed	pea	-	-	1	-	-	-	1
Vicia faba L, seed	faba bean	-	-	14	-	7	15	36
Ficus carica L., seed	fig	6212	3483	4458	67828	8247	36	90264
Ficus carica L., fruit fragment	fig	-	-	8	10	15	-	33
Wild plants								
Laurus cf. *novocanariensis*, leaf fragment	Canarian bay leaf	-	-	3	1	8	-	12
Phoenix canariensis Chabaud, seed	Canarian palm	-	-	1	-	-	-	1
Phoenix canariensis Chabaud, rachilla /perianth	Canarian palm	-	-	3	7	12	-	22
Pinus canariensis C. Sm. ex DC. in Buch, seed	Canarian pine	-	-	8	-	1	1	10
Pinus canariensis C. Sm. ex DC. in Buch, seed scale	Canarian pine	-	-	2	-	-	-	2
Pistacia lentiscus L., seed	mastic tree	-	-	-	1	2	-	3
Visnea mocanera L.f., seed	mocán	-	-	-	-	-	7	7
Total plant remains		6246	3520	11711	72608	9712	178	103975
Insects								
Sitophilus granarius	granary weevil	31	-	493	813	5199	118	6654
Number of silos with weevils		14	-	12	34	32	1	93

Table listing the numbers of plant and insect remains from the granaries analysed. Numbers indicate the amount of seeds and insects, unless otherwise stated.

12 The sediment samples from the silos were dry-sifted through a stack of sieves with 2, 1 and 0.5 mm meshes. All contained abundant desiccated plant remains. Samples from the 2 mm mesh were sorted completely. Yet due to the high density of remains, sorting was only carried out of one quarter of the 1 mm mesh and one eighth of the 0.5 mm mesh. Fig. 5 lists the estimated number of seeds in each granary after multiplying the results of each mesh and calculating the total number of remains in each sample.

13 Identification of the plant remains was carried out with a 8x and 80x binocular microscope by comparing the ancient remains with specimens from the reference collection at the Department of Historical Sciences in the University of Las Palmas. Modern plants were also present in the samples because the silos are no longer sealed. The modern species are excluded in the current paper as this study focuses exclusively on the cultivated and wild plants originally stored in the silos.

Analysis of insect remains

The evidence of insect pests, rare in archaeological storage contexts (Didier 2008; Forbes *et al.* 2014; Panagiotakopulu *et al.* 2010), was systematically recorded. The methods applied to the recovery and identification of insects resemble those of plant remains. The values in fig. 5 correspond to the estimated number of insects in each granary after multiplying the number associated with of each mesh and calculation of the total number of remains in each sample. Identifications were carried out by consulting specialised literature (Buckland 1991; Panagiotakopulu 2001) and by comparison with insects from the reference collection at the Department of Historical Sciences of the University of Las Palmas.

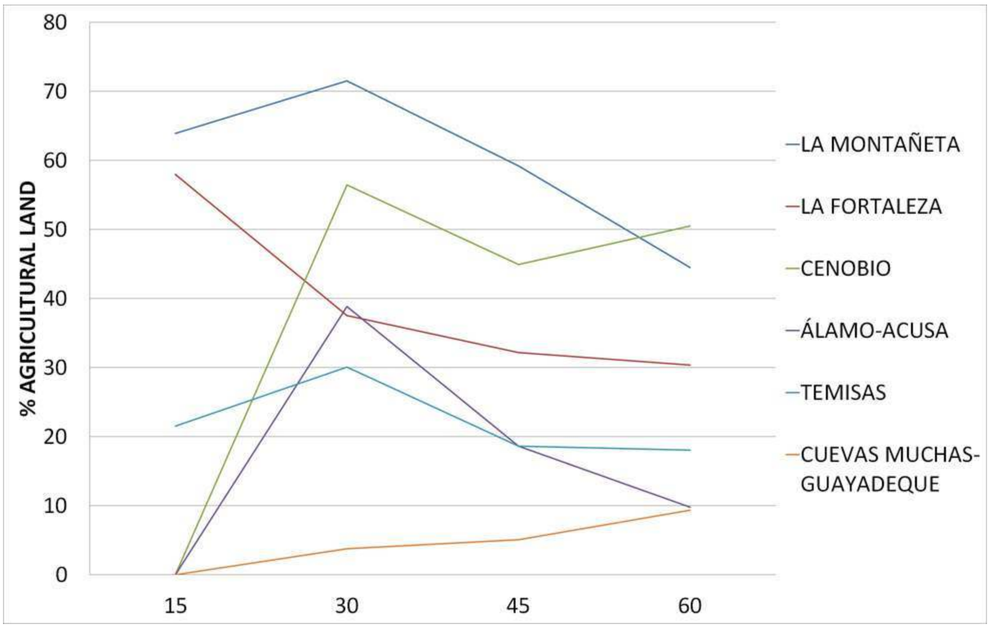
Results and Discussion

The preliminary results of the analyses, presented and commented briefly below, shed light on different aspects of the activities carried out in the ancient granaries.

Location and granary spatial analysis

The results of the analyses of the 15-minute isochrones lines (fig. 6) indicate that the location of the granaries is linked to soil types D and E, soils not suitable for agriculture due to their steep slope, as the granaries were located along cliffs with difficult access. This pattern of selecting the location of the granaries in function of the greatest slope probably results from the necessity of protecting the feature from animals and other population groups (Moreno-Benítez & González-Quintero 2013-2014).

Figure 6.



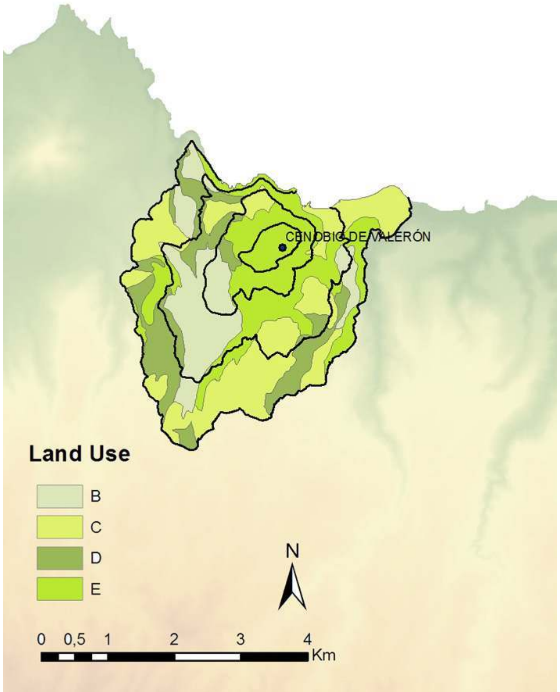
Isochrones map of the granaries and the percentage of agricultural land available to each site. Figures on the X axis indicate the number of minutes.

14 The results of the 30-minute isochrones differ completely. All the granaries, excepting Cuevas Muchas, are located near farm lands. This suggests that after the perception of defense, granary location is linked to proximity to the best farming lands. The fact that the valley below Cuevas Muchas is now depopulated and devoid of farming activity explains the lack of data about farming in the cartography of J. Díaz (1995). However, ethnographic data collected from older residents in the Guayadeque Valley indicate the valley was originally very fertile, especially along its riverbed (Gil-González 2011). Hence the data referring to Cuevas Muchas and the Guayadeque Valley in the study of J. Díaz 1995 requires delicate handling.

15 The results of the 45- and 60-minute isochrone maps suggest a decrease in the percentage of available farming land. Although the total amount of land available in these isochrones is greater than of those of 30-minutes, the reduction in land suitable for farming may be due to diminishing returns resulting from the longer distances to cross between crop fields and granaries.

16 Regarding the question of viewshed, the data indicate that all the granaries had a visual control of their corresponding farm lands in the 15- and 30-minute isochrones, while the more vast 45- and 60-minute isochrones point to a decrease in the visual control.

Figure 7.



Isochrones map of the granary of Cenobio de Valerón.

17 Finally, it must be highlighted that the granary of Cenobio de Valerón is associated with the largest amount of farming land in the 30- and 45-minute isochrones (fig. 7). Thus, it is possible that the number of silos of the Cenobio de Valerón granary, the greatest among all the sites, is directly linked of the amount of available farming land.

Lithic tools and storage

This study of the lithic tools associated with granaries limits itself to a summary of the published results of Cenobio Valerón (Naranjo-Mayor & Rodríguez-Rodríguez 2015). Analyses of the lithic tools from the other granaries is currently in progress.

18 A total of 2,757 lithic objects were recorded at Cenobio de Valerón. Most are architectonical elements such as phonolite slabs serving to seal the silos (2,354 stone artefacts representing 85.4 % of the lithic materials). The list is completed by 45 grinding tools and ground stones as well as 315 knapped stones.

Figure 8.

TYPOLOGY OF THE GRINDING STONE TOOLS FROM CENOBIO OF VALERÓN (FROM LEFT TO RIGHT): A ROTARY QUERN, A BACK AND FORTH QUERN, AND A FRAGMENT OF A MORTAR

PHOTOGRAPHS BY Y. NARANJO-MAYOR

19 The grinding tools consist of rotary querns, saddle querns and mortars, as well as manos and pestles (fig. 8). Use wear analyses indicate that they served to process vegetal materials, notably cereals. Other types of ground tools such as polished picks could have served to carve the silos. The assemblage also includes a pottery burnisher, ten hammers, three rasps and nine multifunctional artefacts. This variety of tools suggests a wide variety of tasks took place at the granary (Naranjo-Mayor & Rodríguez-Rodríguez 2015). Stone tools fashioned in coarse rocks such as basalt or phonolite, in turn, must have served to cut and rework the silos (Naranjo-Mayor & Rodríguez-Rodríguez 2015).

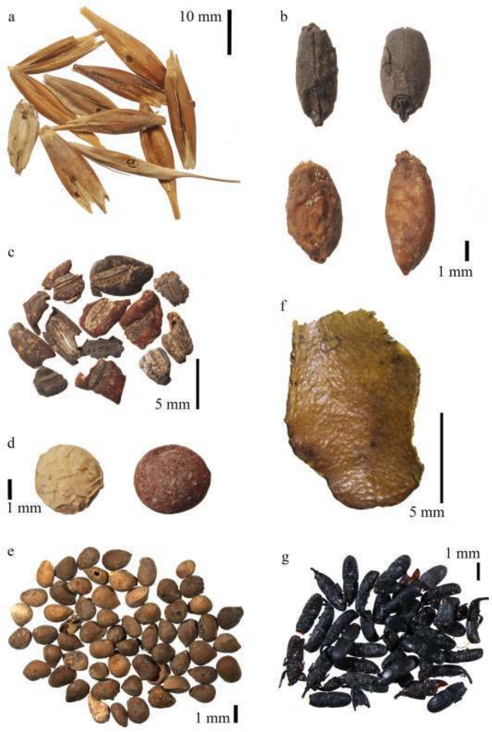
20 Most of knapped tools are obsidian. Use-wear analyses indicate that certain served to cut soft animal material such as meat or leather. This suggests that meat and other animal foods could also have been stored in the silos. Yet the data are still preliminary and more studies are necessary to confirm this hypothesis.

Stored foods

A large number of plant remains (103,975) were collected in the different granaries. The number of seeds, nonetheless, varies from site to site. The highest number of remains comes from Cuevas Muchas, Temisas and Acusa (fig. 5) due to the great number of sampled silos and the excellent conditions of preservation. At Cenobio de Valerón and La Montañeta, two sites that suffered repeated plunder, the number of sampled silos is lower and their preservation is poorer. Only two features were sampled, for the moment, at the site of La Fortaleza.

21 On the whole, six species of cultivated plants were collected from the different silos: six-row hulled barley (*Hordeum vulgare* subsp. *vulgare*), hard wheat (*Triticum durum*), lentil (*Lens culinaris*), broad bean (*Vicia faba*), pea (*Pisum sativum*) and fig (*Ficus carica*).

Figure 9.



ARCHAEOLOGICAL REMAINS OF THE MAIN PLANTS AND INSECT TAXA FOUND IN THE GRANARIES: A) BARLEY, ARTICULATED HULLS (EL ÁLAMO-ACUSA); B) WHEAT, GRAINS (LA FORTALEZA); C) BROAD BEAN, HILUM AND FRAGMENTS OF TESTA (LA FORTALEZA); D) LENTIL, SEEDS (LA FORTALEZA); E) FIG, SEEDS (CENOBIO DE VALERÓN); F) CANARIAN BAY LEAF, FRAGMENT (CUEVAS MUCHAS-GUAYADEQUE); G) GRANARY WEEVILS (EL ÁLAMO-ACUSA)

photographs by J. Morales

22 Barley, found in all the granaries and represented by 12,437 samples, is the most common cereal. This species was collected in the form of grains, articulated sets of hulls and ear fragments (rachis segments) and, in some cases, complete ears. The articulated sets of hulls, although resembling grains, are in fact the result of kernels consumed by beetles as evidenced by the weevil holes on most of the hulls (fig. 9). This species is also identified by articulated basal rachis segments attached to the top section of the culm (straw). These fragments show clear cutting marks on the straw suggesting that the ears were cut from the rest of the plant before being placed in the silos (fig. 10).

23 Durum wheat (*Triticum durum*), evidenced by 1,017 macro-botanical remains, is not as abundant as barley (fig. 5). The samples can be broken down into 999 rachis segments and a meagre number of grains (18). As in the case of barley, some articulated segments of rachis are present, including the basal parts of the ear attached to segments of the straw with the latter showing clear cutting marks (fig. 10).

Figure 10.

Archaeological remains of cereal ears found in the granaries: a) hard wheat, *Triticum durum* (Cuevas Muchas-Guayadeque); b) barley, *Hordeum vulgare* subsp. *vulgare* (Cuevas Muchas-Guayadeque); c) barley, *Hordeum vulgare* subsp. *vulgare* (Cuevas Muchas-Guayadeque)

photographs by J. Morales

24 Pulses, although present in most granaries (except Cenobio de Valerón), are evidenced by smaller numbers than cereals (fig. 5). They include both fragments of seeds and broad bean pods (*Vicia faba*), lentils (*Lens culinaris*) and peas (*Pisum sativum*).

25 Evidence of fruit trees is also identified in all the granaries. Fig (*Ficus carica*) is the most common fruit represented by 90,264 seeds (endocarp), as well as a few peduncles, fruit fragments and complete fruits. It must be taken into account that the great amount of fig seeds in the silos is due to the fact that a single fig can contain up to 1,000 seeds. Hence comparing the values of this fruit with those of other taxa requires caution. Nevertheless, the combination of analyses of plant remains in domestic contexts and human bones with ethnohistorical documents indicate that barley and fig were the staple of Gran Canaria's Pre-Hispanic population (Abreu-Galindo 1977 [1602], Delgado-Darias *et al.* 2005; Morales 2010; Velasco-Vázquez *et al.* 1999).

26 The study also identified a large set of wild taxa corresponding for the most part to weeds commonly found in cereal fields. Most of these remains could have reached the granaries through the wind or animal droppings (Morales *et al.* 2014) and therefore are not included in the current discussion. Among this group of plants are taxa of native flora of Gran Canaria that were probably gathered and stored by the Pre-Hispanic population. These include Canarian bay tree (*Laurus* cf. *novocanariensis)*, Canarian pine (*Pinus canariensis*), 'mocán' (*Visnea mocanera*), mastic tree (*Pistacia lentiscus*), and Canarian date palm (*Phoenix canariensis*).

Storage methods

Granaries and their respective silos were carved in volcanic-tuff, a rock that maintains constant levels of temperature and humidity. Silos were also coated with a thick mortar enhancing their level of insulation.

27 Evidence from the silos, notably a large number of fragments and complete ears with cutting marks, suggest that barley and wheat were stored in the form of ears (Morales *et al.* 2014). Storing cereals in this manner was advantageous for long-term storage as the grains were naturally protected by their hulls and glumes (Alonso 1999; Meurers-Balke & Lüning 1992; Sigaut 1988). This method seems to be the same for pulses and wild fruits. Pulse pods and some indeterminate pod peduncles are recorded at some silos. Peduncles link the pod with the plant and usually remain attached to the pod when the fruit is harvested. Therefore, it is likely that pulses were stored in their pods to prevent insect infestation.

28 Figs were stored whole. Ethnohistorical records of the first Europeans confirm that the Pre-Hispanic population stored dried figs for year-round use (Abreu-Galindo 1977:161 [1602]). The identification of bunch fragments of Canarian palm suggests that dates were stored in bunches. Like figs, ethnographic records reveal that dates were dried and stored in the recent past (Morales 2010:169). The presence of pine seed scales indicates that the seeds were stored inside the cones. To harvest pine nuts, cones are usually gathered when closed and unripe (Morales *et al.* 2015) avoiding damage to the seeds during long-term storage.

29 The presence of grinding tools bearing traces of plant processing use-wear suggest that this activity was frequent at the granaries. On the other hand, although analyses of plant remain at settlements show abundant evidence of seeds, ear fragments such as rachis segments are not common (Morales 2010). The lack of evidence of cereal processing in settlements, coupled with the abundance of rachis segments and grinding tools in the granaries, may be evidence that grains were separated from the straw in the granaries, and only later transported to the settlements for consumption.

30 Storage is an intermediary stage embedded within the sequence of food production, and therefore offers very interesting information about the processing, distribution and consumption of food in the past (Forbes & Foxhall 1995).

Insect pests and insecticide plants

Evidence of insect pests are found in most of the samples despite the use of different storage methods by the Pre-Hispanic population. Grains showing insect damage, as well as the insects themselves, are recorded in all the granaries except La Montañeta (fig. 9). Although the analyses are currently in progress, many remains (minimum 6,624) of granary weevils (*Sitophilus granarius*) have been identified. The site of Temisas has the greatest number (5,199) of specimens. A radiocarbon analysis of the weevils at El Álamo-Acusa yields a date (980 ± 30 BP; Cal AD 1080 – 1150) that confirms that these pests were contemporary to the cereal grains stored in the silos (Morales *et al.* 2014).

31 The granary weevil is one of the most common insects infesting grains stored in the world (Buckland 1991; King 2013; Panagiotakopulu 2001). *S. granarius* is an especially significant evidence as it is completely synanthropic and only lives and reproduces

exclusively in stored grains and is unknown in the wild (Plarre 2010). The evidence of granary weevils in the silos confirms that these features indeed served to store grains. On the other hand, the high number of weevils in the silos indicates that these pests were a major problem for the long-term storage. Yet historical texts written by the first Europeans arriving in the Canaries between the 14^{th} and 16^{th} centuries indicate that the Pre-Hispanic population of Gran Canaria could store grains in silos for several years without suffering damage from weevils (Morales-Padrón 1993: 436 [1500/1525]).

32 Populations in the Mediterranean Basin traditionally reverted to several inorganic products such as sulphur, natron, or salt to repel insects from stored grains. Yet they also often reverted to specific plants to manage this problem (Lefébure 1985; Panagiotakopulu *et al.* 1995). Traditional farmers in the Canaries until recently used Canarian bay leaves (*Laurus novocanariensis*), eucalyptus, and other plants to repel the pests (Álvarez-Escobar 2011; Rodilla *et al.* 2008). Other plants serving as insecticide in the Mediterranean Basin are coriander (*Coriandrum sativum*), onion (*Allium cepa*), rue (*Ruta graveolens*) and bay leaf (*Laurus nobilis*) (Panagiotakopulu *et al.* 1995). Nevertheless, none of these elements have been identified so far in an archaeological context of storage.

33 Desiccated fragments of Canarian bay leaf (*Laurus* cf. *novocanariensis*) are identified in the granaries of El Álamo, Cuevas Muchas and Temisas. Certain remains dated by radiocarbon, such as the sample of El Álamo (930 ± 30 BP: Cal AD 1030-1210), confirm their great age (Morales *et al.* 2014). Other samples from Cuevas Muchas and Temisas date respectively to 480 ± 30 BP (Cal AD 1410-1450) and 510 ± 30 BP (Cal AD 1400-1440). The radiocarbon dates of leaf fragments therefore indicate that Canarian bay leaf formed part of the original content of the silos. Biochemical analyses of a compound in this type of leaf confirm that their oils inhibit consumption by insects, are strongly antifungal, and inhibit seed germination (Rodilla *et al.* 2008). These properties are in fact very advantageous for long-term storage of grains as they repel insects and maintain seed dormancy. Thus, we interpret the presence of Canarian bay leaf in the Canarian granaries as a means to repel insects. To our knowledge, this is the first direct archaeological evidence of the use of insecticide plants in the framework of food storage.

Conclusions

The preliminary results advanced in this paper provide a first multidisciplinary approach to the study of long-term storage methods in the past. The current data indicate that the Pre-Hispanic population of Gran Canaria built large communal granaries away from settlements in cliffs with difficult access to protect their stores from animals and people. The granaries were located, nonetheless, within eyesight of the fields at a distance corresponding to a 30-45 minute walk. The combination of seeds and stone tools indicate that granaries served not only to store cereals, pulses and fruits, but to process them. To assure a better conservation, the grains were stored in the form of ears and pods inside silos carved in the rock. The stores were accompanied by Canarian bay leaves placed inside the silos to repel insects. Nevertheless, there is clear evidence that the stores were damaged by weevils indicating the serious problem these insects represented for long-term storage.

34 The results of the current study are preliminary. Future research should not only focus on completing insect and stone tool analyses, but also on analyses of the animal remains and of the structural design of the silos. It is evident that the Pre-Hispanic granaries of

Gran Canaria present exceptional conditions of preservation and bear a tremendous potential to shed light in past storage methods.

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ABSTRACTS

Insect pests are one of the main problems in the long-term storage of food, especially for grains. It has been estimated that before chemical insecticides were used systematically, insects damaged around 10-20 % of the stored grain, and in certain conditions they could spoil the whole harvest. There are historical documents recording the use of organic and inorganic products to kill or dispel the insect, but there is little archaeological data about this important aspect in food storage. This is partially due to the lack of in situ finds of conserved ancient foods. What methods and techniques were used to store food and avoid insect pests in the past? In order to answer this question, this paper aims to provide new data on the methods and techniques employed in the past for the long-term storage of food plants by presenting the preliminary results of an analysis carried out in the framework of a multidisciplinary project of a group of granaries on the Island of Gran Canaria (Canary Islands, Spain) from the Pre-Hispanic period (*ca.* 500-1500 AD). The indigenous populations of Gran Canaria were farmers that procured most of their food from cultivated plants and they built many granaries for their storage. The silos analyzed in the current work still contained archaeological remains of cereals, pulses, and both cultivated and wild fruits that were radiocarbon dated between 700-1440 AD. To assure a better conservation, the grains were originally stored in the form of ears and pods inside silos carved in the rock. The stores were accompanied by Canarian bay leaves placed inside the silos to repel insects. Nevertheless, there is clear evidence that the stores were damaged by weevils indicating the serious problem these insects represented for long-term storage.

Les insectes constituent l'un des principaux problèmes rencontrés lorsqu'il s'agit de stocker sur le long terme des aliments, en particulier, des céréales. Avant l'emploi d'insecticides chimiques, les insectes, s'il n'abîmaient pas la totalité de la récolte, endommageaient au moins 10 à 20% du grain stocké. Des documents historiques témoignent de l'utilisation de produits organiques et inorganiques pour éliminer ou chasser les insectes. En revanche, les données archéologiques sur ce sujet si important pour le stockage sont rares. Ceci est en partie dû au manque de découvertes d'aliments anciens conservés *in situ*.
Quelles méthodes et techniques ont été utilisées dans le passé pour stocker les denrées et éviter les infestations par les insectes? Pour répondre à cette question, nous présentons les résultats préliminaires d'une étude conduite dans le cadre d'un projet pluridisciplinaire sur un ensemble de greniers de l'île de Gran Canaria (îles Canaries, Espagne) datant de la période préhispanique (environ 500-1500 apr. J.-C.). Les populations autochtones de Gran Canaria étaient des agriculteurs. Leurs denrées alimentaires étaient avant tout des plantes cultivées. Ils ont construit de nombreux greniers pour leur stockage. Les silos analysés dans le cadre de ce travail contiennent encore des restes archéologiques de céréales, de légumineuses et de fruits cultivés et sauvages datant du 700 à 1440 apr. J.-C. Pour assurer une meilleure conservation, des épis et des légumes conservés dans leur cosse ont été stockés dans des silos creusés dans la roche. Un dépôt intentionnel de feuilles de laurier des Canaries a été identifié : il servait surement à repousser les insectes. Cela s'est avéré insuffisant : les produits de la récolte ont été endommagés par des

charançons. Le problème que ces insectes représentaient pour le stockage à long terme est donc avéré.

INDEX

Mots-clés: îles Canaries, préhispanique, stockage, analyse spatiale, pierres de meulage, archéobotanique, archéoentomologie
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